THERMAL AND METABOLIC RESPONSES OF ARCTIC INDIANS TO A STANDARD MODERATE COLD EXPOSURE AT THE END OF WINTER

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ABSTRACT

Oxygen consumption, skin temperature and rectal temperature during nights of cold exposure were measured in eight Indian men from a remote arctic village who had been similarly studied the previous fall. The metabolic response of the Indians to cold exposure was similar in the spring to that observed in the fall studies. All subjects showed a general increase of about 30% in O_2 consumption during the night. In addition, the basal metabolic rate of four subjects measured was slightly above the DuBois standards, as in the fall. A decline in rectal and skin temperatures throughout the night was observed to be similar to that of the same subjects in the fall, with the exception that the surface temperatures of arms and legs were slightly cooler in the spring. It was concluded that, except for a tendency toward heat conservation by cooling of extremities, no metabolic or thermal changes of a seasonal nature had taken place in these subjects during the arctic winter.

THERMAL AND METABOLIC RESPONSES OF ARCTIC INDIANS TO A STANDARD MODERATE COLD EXPOSURE AT THE END OF WINTER*

Within recent years, several studies have been carried out with the purpose of determining the nature of human adaptation to cold. The investigations have involved both Caucasians exposed to cold for periods of weeks or months and native peoples habituated to cold or dwelling in arctic regions.

Results of experimental exposure of white subjects for periods of weeks or months have demonstrated increased ability to maintain warm extremities (Scholander, et al., 1958; Mackworth, 1955). Increased metabolic compensation has also been observed (Scholander, et al, 1958), but, by contrast, another investigation (Carlson, et al., 1953) has provided evidence for a lessened metabolic response by a mechanism which might be called "metabolic sparing" through an increase in the superficial tissues of the body shell participating in heat loss. This means essentially an increase in physiological insulation. Presumably this general cooling was accomplished at nearly the same average skin temperature as in the unacclimatized person by maintenance of a less steep tissue temperature gradient. Furthermore, the elevated extremity temperatures appear to be maintained by slight adjustments of limb circulation affecting heat exchange throughout the limb.

Investigations have recently been extended to the aborigines of central (Scholander, et al., 1958; Hammel, et al., 1959) and northern Australia (Hammel, et al., 1959). The former peoples are scantily clad and customarily sleep naked even in near-freezing temperatures of winter warmed only by small fires. The aborigines of tropical northern Australia are rarely cold exposed. The procedures employed in these studies were the same as those used in an acclimatization study on young Norwegians (Scholander, et al., 1958). Metabolic and body temperatures were measured during sleep at 3^{o} C with subjects protected by one blanket. Both the acclimatized Norwegian group and the central Australian aborigines slept well throughout the night, although with quite different physiological responses. The Norwegians increased metabolism by vigorous shivering and consequently cooled less than the aborigines who did not shiver. Their metabolism remained unchanged or fell during the night, and their skin and rectal temperatures fell steadily. The white controls for both experiments, however, were uncomfortably cold throughout the night and slept only briefly between bouts of shivering. The tropical Australian natives slept better than control whites

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and occupied an intermediate position between the whites and the central Australian natives with respect to their thermal and metabolic responses.

Similar investigations (Irving, et al., 1960) were performed in an Indian village of the Canadian Arctic, Old Crow, Yukon Territory. No general metabolic or thermal adaptation was apparent. Both white control and Indian experimental subjects responded to night cold exposure in a manner similar to that of white controls in all previous studies of the series. They showed an increase of about 50% in metabolic rate and a general decline in rectal and skin temperatures. Hand calorimetry experiments (Elsner, et al., unpublished) demonstrated, however, that the Indians differed from the whites in being able to evolve more heat from the hands during hand cooling. This difference persisted during general body cooling and might be related to the local habits of work on and near the river involving much hand cooling while fishing and transporting goods.

The question of possible seasonal acclimation in the people of Old Crow remains. The recently completed study there was conducted during the relatively mild late summer and early fall. Winter activities are such as to make intermittent exposure and cool sleeping frequent experiences. Any acclimatizing responses should be detectable by the experimental techniques employed in the earlier study in Old Crow and in all former studies of this series. These investigations comparing the same subjects at different seasons would provide an answer to the question raised by the indications of no apparent general year-round metabolic and thermal adaptation in these subjects.

METHODS

The physical characteristics of the subjects studied are listed in Table I. Changes in their body weights and their skin-fold thicknesses were small.

Only night runs were carried out and the experimental procedure was essentially the same as that used during the fall.

A field laboratory was established in a log cabin. One room was kept warm with a temperature of 20° to 25° C and was used for the gas analytical and temperature recording work. An adjacent experimental cold room was arranged, and its temperature regulated by adjustment of the opening to the heated laboratory room. Thus, the temperature in the experimental room was maintained between 0° and 3° C.

TABLE I

PHYSICAL CHARACTERISTICS OF THE EXPERIMENTAL SUBJECTS

Subject	Age in Years	Height in cm	Weight in kg		Lean Body Mass in kg		Surface Area M^2	
			Fall	Spring	Fall	Spring	Fall	Spring
B. C.	18	170	67	70	54	55	1.77	1.79
P. B.	31	172	63	66	58	58	1.73	1.76
J. T.	25	157	58	57	51	48	1.57	1.55
J. K.	34	165	64	66	53	54	1.70	1.71
A. A.	36	170	65	68	57	56	1.73	1.77
A. P.	25	171	68	70	60	60	1.80	1.81
A. C.	21	169	55	59	47	48	1.62	1.66
D. N.	37	162	68	69	59	60	1.72	1.73
Mean	28.3	167	63.5	65.6	54.9	54.9	1.71	1.72

TABLE II

BASAL METABOLIC RATE OF FOUR ARCTIC INDIANS IN THE FALL AND SPRING

Subject	O_2 ml/min		% of Du Bois Standard		ml/min/kg Body Mass		ml/min/kg Lean Body Mass	
	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring
A. A.	290	237	127	101	4.46	3.49	5.09	4.23
P. B.	307	284	130	121	4.87	4.31	5.29	4.90
J. K.	231	247	103	108	3.61	3.74	4.36	4.57
J. T.	245	221	112	105	4.22	3.88	4.80	4.60

Two subjects were studied simultaneously. They reported in the laboratory at about 2100 hours, approximately 3 hours after they had taken their usual evening meal at home. The subjects then entered the blanket sleeping bag covered with one layer of thin canvas. The bags offer about 1 Clo of insulation, sufficient for comfortable rest at 20° C. The subjects reclined on beds of 1/2-inch mesh hardware cloth. Their heads were encased in transparent plastic boxes and the necks sealed airtight by means of a rubber sleeve. Outdoor air was pumped through the hoods at a rate such that the CO_2 concentration in the box did not exceed 1%. The air drawn through was metered by a Müller gas meter, which also pumped aliquot samples into small rubber Douglas bags. Half-hour sampling periods were used, allowing 5 to 10 minutes to empty and change the bags. Small samples were taken out in the bags and oxygen tension was measured with the Pauling oxygen analyzer (Beckman Model C). Every second sample was checked on the Scholander 0.5-cc gas analyzer; CO_2 was also determined. The R.Q. found by this method was then used for the calculation of O_2 intake for that sample and for the previous sample measured in the oxygen analyzer.

Skin temperatures were measured by 30-gauge copper-constantan thermocouples taped to the skin and read on a Leeds and Northrup portable precision potentiometer (No. 8662) at half-hour intervals during the experiment. The thermojunctions were made by soldering the twisted wire ends, then coating them with clear fingernail polish for electrical insulation. Each thermocouple was held firmly in place on the skin by a 3" by 2" piece of adhesive tape. They were placed as follows: dorsum of foot, lateral side of lower leg, lateral side of thigh, pectoral surface, subscapula region, lateral side of upper arm, dorsum of hand, and forehead. Rectal temperature was obtained by a similar thermocouple soldered into a silver tip mounted in a flexible polyethylene tubing. The silver tip was coated with fingernail polish. The thermocouple was inserted 15 cm and taped in place.

The experiments usually started at about 2200 hours. During the first hour, the room was kept warm and the subjects were covered with an extra blanket in order to establish their normal resting values. As very high values in general were found during this period, the subjects' resting values were taken another day just before and after noon. In addition, the metabolic rate was determined on four Indians under the usual standard basal conditions after they had slept comfortably in the laboratory during the previous night. These measurements were made by collecting undiluted expired air which was analyzed by means of the Scholander 0.5-cc gas analyzer.

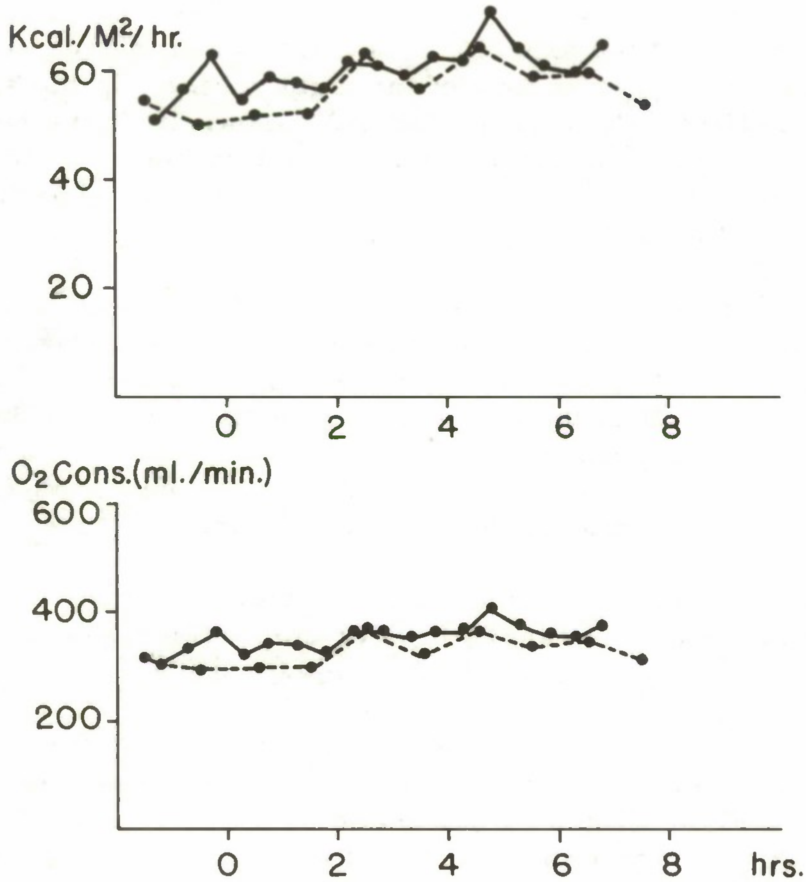


Figure 1. Averaged metabolic rate and O_2 consumption during night experiments in fall (dashed line) and spring (solid line). Onset of cold exposure at time o.

RESULTS

Figure 1 shows the averaged metabolic rate and oxygen consumption during the night experiments in fall and spring. The metabolic rate taken during the first hour of the experimental night, when the subjects were kept warm, is somewhat higher in four of the eight subjects in the spring than in comparable experiments during the fall. As known from the repeat runs undertaken on the same subjects, there exists considerable individual differences from time to time in metabolic rate. No other general differences are discernible between the subjects in fall or spring.

Determinations of the basal metabolic rate during standard basal conditions were performed on four subjects. The results are shown in Table II and are compared with data obtained in the fall. The Indians have higher basal metabolic rates than the average found by Benedict who investigated a large number of young white men. It is apparent that no important changes have taken place in the normal resting and in basal metabolic rate of the Indians after having lived through an arctic winter.

The individual data for all the subjects studied during the standard night cold exposure are shown in Figure 2. For comparison, the corresponding fall data are included.

The individual skin temperature measurements at various sites for all eight subjects are plotted in Figures 3 through 8. The average skin temperature is shown in Figure 9 and rectal temperature in Figure 10. The solid line connects the average temperature for the same measurement in these subjects in the fall. In Figures 7, 8, and 9, the dotted line connects the averages of the temperatures in the spring experiments.

The average skin temperature values of Figure 9 were obtained by weighing the individual determinations of skin temperature by the following factors corresponding with regional surface areas: head, 0.07; hand, 0.05; arm, 0.14; back, 0.17; chest, 0.18; thigh, 0.19; lower leg, 0.13; and foot, 0.07. These weighted skin temperatures were totaled to obtain the average skin temperature.

Table III shows the comparative measurements of the percentage of oxygen in air drawn through the hoods as measured by the Scholander apparatus and the Beckman oxygen analyzer.

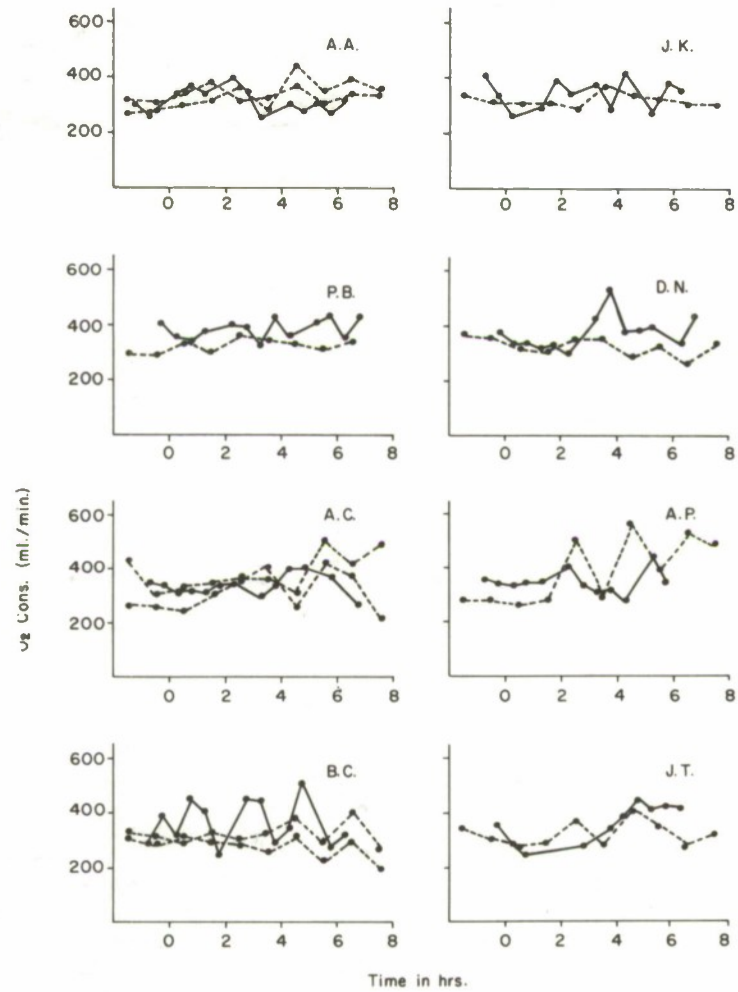
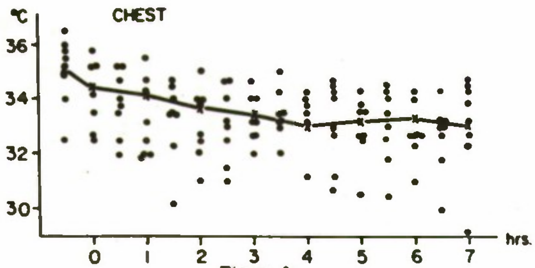


Figure 2. O2 consumption of individual subjects in fall (dashed line) and spring (solid line).



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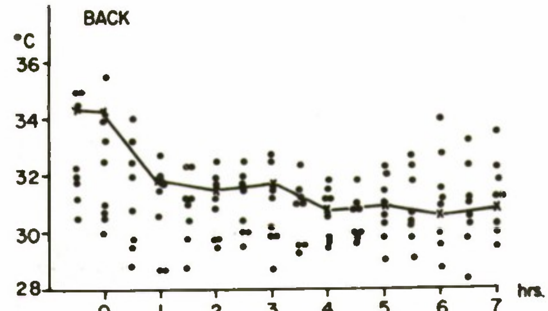

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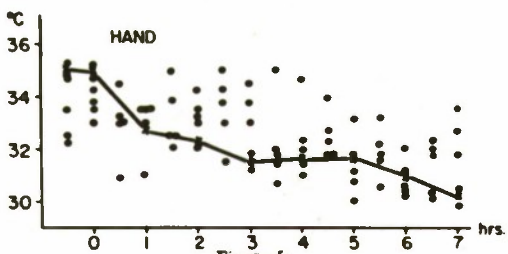
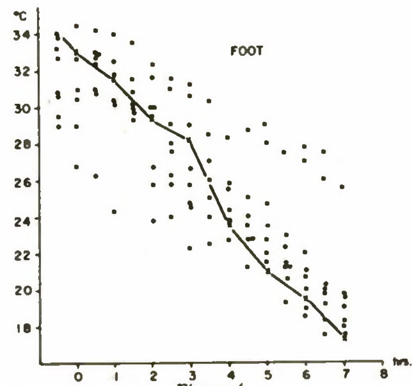


Figure 5.



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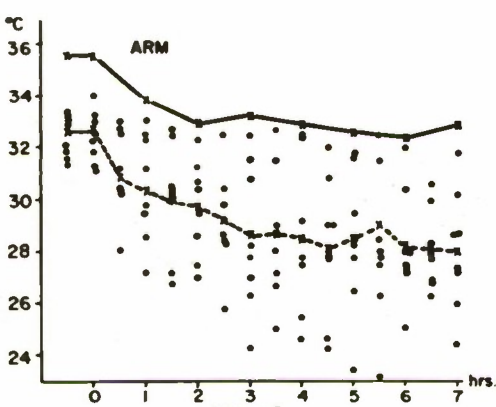

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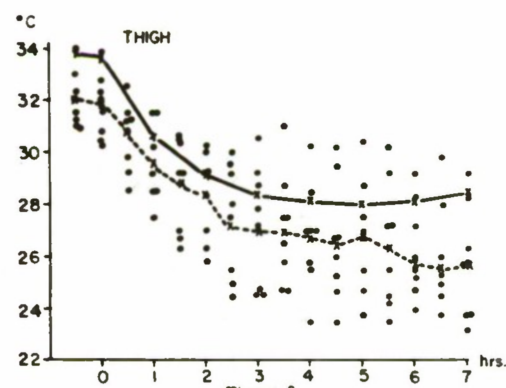

Figure 8.

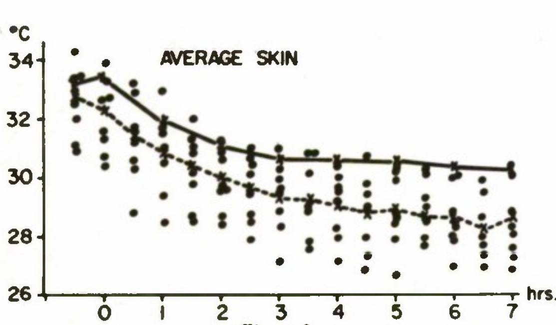

Figure 9.

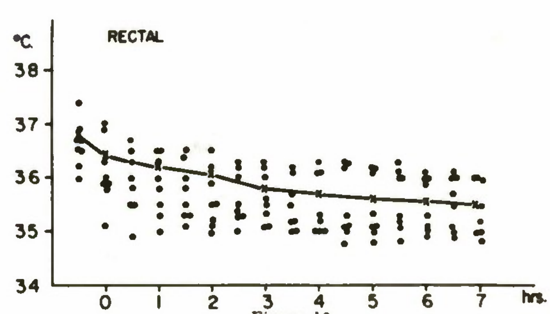

Figure 10.

Figures 3-10. Skin and rectal temperatures during night cold exposure. The x's connected by solid line, indicate means of similar determinations on the same subjects in the fall. Dashed lines on plots of thigh, arm, and average skin temperatures connect averages of spring data.

TABLE III

COMPARISON OF BECKMAN AND SCHOLANDER OXYGEN ANALYSIS

Scholander	Beckman	Beckman - Scholander	Scholander	Beckman	Beckman - Scholander
20.27	20.32	+.05	20.12	20.10	-.02
20.03	20.05	+.02	19.90	19.81	-.09
20.31	20.29	-.02	19.98	19.92	-.06
20.15	20.19	+.04	20.08	20.08	.00
20.02	19.94	-.08	20.11	20.11	.00
20.10	20.10	.00	19.68	19.63	-.05
20.27	20.30	+.03	20.12	20.00	-.12
19.88	19.92	+.04	19.79	19.66	-.13
20.05	20.10	+.05	19.97	19.93	-.04
20.15	20.19	+.04	19.78	19.70	-.08
20.21	20.19	-.02	19.97	19.89	-.08
20.20	20.19	-.01	19.87	19.75	-.12
19.69	19.75	+.06	19.69	19.73	+.04
20.29	20.39	+.10	19.66	19.52	-.14
20.04	20.07	+.03	19.79	19.82	+.03

DISCUSSION

Reference is made to Figures 1 and 2, showing the comparisons of fall and spring metabolic data for the same subjects, which indicate no general seasonal change. It can be concluded that no seasonal metabolic acclimation has taken place. There is a definite suggestion of a change in thermal response in the observation of cooler limbs (Figs. 7 and 8) resulting in a lower mean skin temperature (Fig. 9). This observation supports the hypothesis of Carlson, et al. (1953) that the process of cold acclimation is accompanied by increased physiological insulation. The fact that hand and foot temperatures are not different from the measurements in the fall (Figs. 5 and 6) despite the lower temperatures of the arms and legs, argues for a more effective heat exchange through the limbs. Rennie (1958) has described a similar response in white subjects in prolonged cold exposure. A more effective heat exchange indicates a less steep thermal gradient in the limbs. The lack of an appropriate decrease in metabolism is not easily explained. It might be more readily seen in an experiment involving more severe cold stress.

The question of the extent of cold exposure in the Indian subjects is of considerable importance. It is sometimes suggested that peoples native to the Arctic avoid cold exposure by virtue of their superior clothing and well-insulated dwellings. It is clear that harmful hypothermia is not generally experienced. The subjects of this experiment, however, could scarcely have avoided considerable periods of prolonged negative heat balance. They all had spent much of the winter engaged in travel and living away from the village in pursuit of their customary activities of hunting, trapping, and wood cutting. Except for moosehide mittens and moccasins of excellent home manufacture, their clothing consists generally of wool and cotton garments inferior to fur clothing. The winter climate of the region is particularly severe. Temperatures lie below 0^{o} F for weeks at a time, with frequent readings in the neighborhood of -50^{o} to -60^{o} F. Harsh winds characteristically accompany the frequent storm periods. It can be argued that the methods employed were not sufficiently sensitive to reveal changes in metabolic response which might occur. These same methods have, however, revealed important differences between control whites and natives having a range of clothing between the customarily naked Australian aborigines and the warmly dressed Lapps.

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